10.0 AIRPLANE OPERATIONS AND MAINTENANCE

The Airplane Operation and Maintenance Task Team was assembled by the Working Group to support the fuel tank inerting study. The primary functions of this team were to

- Review operational and maintenance data on existing fuel tank inerting systems.
- Evaluate the effect of the proposed inerting system design concepts on airplane operations, maintenance, and fleet planning.
- Evaluate the cost impact of the proposed inerting system concepts on flight operations, ground operations, and maintenance.
- Provide technical expertise in the area of airline and airplane operations and maintenance to the other Working Group teams.
- Document the results of the team's findings.

The team comprised individuals with extensive experience in airline flight operations, maintenance, ground operations, engineering, and aviation regulations.

10.1 METHODOLOGY

Data Review

The team's first task was to search for and review all available documentation relating to the operation, maintainability, and reliability of airplane fuel tank inerting systems. The team searched libraries and databases belonging to U.S. and European regulatory agencies, the Airline Pilots Association (ALPA), the petroleum industry, airplane manufacturers, and U.S. military services. The team also searched the Internet for information.

Little publicly available data on airplane fuel tank inerting systems exists. The team did identify some reports, primarily FAA studies, including one on the modification of a DC-9 to incorporate a fuel tank inerting system 30 years ago. With the exception of the data produced as a result of the 1998 ARAC FTHWG report and a 2000 FAA Technical Center report on GBI, none of these reports included any operational or maintenance data relevant to the current study.

The team identified several military fuel tank inerting system applications similar to those being considered for this study. However, the team obtained very little operational, maintenance, or reliability data on those systems because that data is classified.

Inerting System Concept Review

As information became available from the Ground-Based Inerting Designs and the Onboard Inerting Designs teams, the Airplane Operation and Maintenance Task Team began reviewing the systems to identify operational and maintainability considerations for each concept. We initially evaluated each concept to identify how it might affect airplane flight operations, ground operations, dispatch reliability, maintainability, and training requirements. We also considered the potential effect on passenger, crew, and maintenance personnel safety.

After this initial evaluation, the team split up into subteams to begin detailed analyses. The four subteams addressed flight and ground operations, airplane modification and retrofit, scheduled maintenance, and unscheduled maintenance and reliability.

Flight and Ground Operation Subteam. This subteam identified and quantified the operational issues, impact, and costs associated with flight operations and gate or ramp operations needed to support airplanes equipped with inerting systems for each of the inerting systems concepts. They also analyzed and developed data relating to training requirements, airplane servicing, flight dispatch requirements and resources, cost-to-carry estimates, flight operating manual procedures, and manual revisions for each of the airplane-system combinations.

Modification and Retrofit Subteam. This subteam identified and quantified the costs and impact associated with modification of each existing airplane types to install the various inerting systems. The sub-team assumed that the modification would be done according to an airplane manufacturer service bulletin that provided modification data, and that the manufacturer would make available modification kits. The subteam considered two different modification scenarios: First, the airplane is modified during a regularly scheduled heavy maintenance check. Second, the airplane is modified during a dedicated maintenance visit. The advantage of the first scenario is that access to most maintenance areas is already open for the regular maintenance check, which would reduce the total labor requirement, cost of modification, and airplane time out of service.

They developed data and estimations for each of the airplane-system combinations. These estimates were to include but not be limited to material and kit costs, modification labor-hours, engineering support requirements, technical publication revisions, airplane time out of revenue service, spares and training requirements, and any other issues related to the retrofit of inerting systems on existing airplanes.

Scheduled Maintenance Subteam. This subteam identified and quantified the costs and impact associated with the routine maintenance of the inerting system as well as any effects the inerting systems might have on the maintenance requirements of other airplane systems or equipment.

The subteam developed data for each of the airplane-system combinations. This data would include but would not be limited to airplane and component maintenance tasks, task intervals, task labor-hours, estimate of annual scheduled maintenance labor-hours, annual material costs, and the impact on check schedules, tooling requirements, and all other aspects of scheduled maintenance.

Unscheduled Maintenance Subteam. This subteam identified and quantified the costs and impacts associated with the nonroutine maintenance of the inerting system. They also would work with the Design, Rulemaking, and Safety teams to define MMEL requirements and limitations.

They also developed data for the cost and impact of unscheduled maintenance on each of the airplane-system combinations, including but not limited to

- Line maintenance tasks.
- Line maintenance labor-hours for troubleshooting and repair based on reliability data.
- Delay and cancellation rates.
- Airplane-on-ground time.
- Line maintenance training requirements and costs
- Component overhaul interval, labor, and material costs.
- All other impacts related to unscheduled maintenance and system reliability as measured in MTBF or MTBUR.

10.1.1 Modification

General

The inerting systems would be installed by way of modification or retrofit. OEMs would retrofit airplanes in production. OEMs would also need to provide modification to operators through a service bulletin. Operators, maintenance facilities, or OEMs will modify in-service airplanes.

An FAA-approved OEM service bulletin for retrofitting an inerting system should be available before any final rule compliance date is set for retrofit of in-service airplanes. Failure to do this has caused problems for operators in the past. For example, in 1998 the FAA issued an AD for 747-100/-200/-300/-SP/-SR–series airplanes on changing wire separation requirements for fuel quantity indicating system wiring. Although an approved retrofit solution was not available, a 3-year AD compliance time for airplane modification was set. The FAA expected the OEM to complete design changes, gain approval, and make service bulletins available within 1 year of the effective date of the AD. This would have allowed the operators 2 years to modify their affected fleet. However, the FAA-approved retrofit solutions did not become available until almost 24 months into the compliance period, thereby significantly affecting the operator's ability to complete the modifications within the remaining compliance time. Because of the potential for delays in the design approval, it is critical that before the establishment of any compliance date requiring installation of an inerting system, an approved service bulletin must be available. This will ensure that operators have sufficient time to complete the modifications within the compliance period of a rule. Because of the scope of the modification, it must be accomplished during a heavy maintenance check or a special visit. Estimates have been developed for both scenarios.

The modification estimations are split into two major parts. The first is the nonrecurring costs that comprise engineering time, technical publication changes, and material control. The labor-hour estimates for these nonrecurring costs are the same for all airplane categories and are per airplane type per operator. The second part of the modification estimate includes recurring costs and comprises actual airplane modification time. This part of the estimate is per airplane.

Appendix F, Airplane Operation and Maintenance Task Team Final Report, addendum F.A.1, shows the total modification estimate. The following sections present a short description of each topic.

Engineering

Before a modification can be accomplished, the operator's engineering department must review the OEM service bulletin to determine applicability and check for variations in airplane configurations. Then Engineering must write modification orders, including creation of the necessary drawings and job cards, and coordinate with the maintenance and material planning groups. After the modification order has been completed and is ready for production, Engineering has to create the necessary tracking numbers and maintain the records for all components and their trends. The maintenance program must be updated before release of the first modified airplanes. The engineer assigned to this modification becomes the project manager. In addition to the responsibilities described here, he or she will be assisting and monitoring the progress of this modification.

Technical Publications

The introduction of the inerting system affects the following technical publications:

- Aircraft Maintenance Manual.
- Illustrated Part List.
- Component Maintenance Manual.
- Aircraft Flight Manual.

- Flight Operations Manual.
- Structural Repair Manual.
- Fueling Manual.
- Ramp Maintenance Manual.
- General Maintenance Manual (including company procedures).
- Wiring Diagram Manual.
- Weight and Balance Manual.

In the modification estimation analyses, the team assumes that the normal revision procedures of the airplane manufacturer are used. The estimated time is the time required to revise the manuals.

Material Control and Kits

The inerting system introduces new serialized parts and consumable parts. Those new parts have to be added to the company's databases. Because insufficient data exists on the inerting system, we did not account for the material cost of consumables.

Before the establishment of any compliance date requiring installation of an inerting system, modification kits must be available and the airframe manufacturers should coordinate the flow of kits to the operators. In this way, large operators will not adversely affect the availability of kits for smaller operators.

Kit costs—the price of the kit, its storage costs, and the labor-hours needed to check it—are not taken into account because of the large variation among airplanes, which prevents the use of detailed generic data and pricing.

Project Estimation

For the modification estimation, the following airplanes were used as examples of each of the six category airplanes:

- Large-airplane category: Boeing 747 series.
- Medium-airplane category: Boeing 767 and MD-11.
- Small-airplane category: Boeing 737.
- Regional turbofan–airplane category: Fokker 28 and 70.
- Regional turboprop–airplane category: No airplane[1] .
- Business jet–airplane category: Gulfstream IV.

Appendix F, addendum F.A.2, shows the task with the labor-hours to perform the project. For this estimation, we assumed that the airplane has integrated tanks. Rubber cells are used by the Fokker 28/70/100–series airplane and as auxiliary tanks on some other transport airplanes. Introduction of the inerting system requires modification or redesign of the rubber cells. For the regional turbofan airplanes estimates were developed to show the differences in labor-hours of integral and bagged fuel tanks. Neither is the time required for moving or replacing existing installations to accommodate the piping of the inerting system.

[1] We made no estimate for the regional turboprop airplane category because we could not find a company that does the maintenance for propeller airplanes with a CWT. Fokker Services, which made the estimate for the regional turbofan airplanes, told us that the Fokker 27, 50, and 60 airplanes (turboprop airplanes) do not have a CWT.

The engineering support requirements (e.g., engineering, technical publications, and material management) for retrofit of an operator fleet are based on a nominal fleet size.

Airplane Out-of-Service Time Estimate

We made the following assumptions to estimate the downtime for the airplane:

- Modification is accomplished based on a 5-day workweek.
- There are three shifts each with 10 people (5 mechanics, 3 avionics, and 2 sheet metal workers).

Maintenance Training

The basic training requirement for this fuel tank inerting modification consists of classroom lectures, use of the jet airplane maintenance fundamentals, CBT courseware, basic training workshops, and practical training on in-service airplanes at a maintenance organization. Substantial time is needed to educate and train the professional maintenance technicians who will be responsible for safely handling and maintaining airplanes equipped with inerting systems.

Operator maintenance and ground training departments and vendor and manufacturer training departments will need substantial time to create and present all necessary training materials for the different kinds of inerting systems. The diversity of airplane fleets and available inerting systems will compound this challenge.

Existing training manuals will need to be revised to reflect airplane modifications and operational requirements created by fuel tank inerting.

There are significant differences in training regulations among various countries. An accurate estimate would require knowing the exact number of licensed mechanics and the average number of licensed mechanics per airplane per operator. An additional factor is the fact that some operators contract with training centers to educate their maintenance personnel. Because of these and other factors the team was not able to make a labor-hours estimate for training costs. However, the team described the impact on maintenance training from the introduction of inerting systems.

10.1.2 MEL Relief

FARs require that all equipment installed on an airplane be in compliance with the airworthiness standards and that operating rules be operative. However, the FARs also permit the publication of an MEL where compliance with certain equipment requirements is not necessary in the interests of safety under all operating conditions. Experience has shown that with the various levels of redundancy designed into an airplane, operation of every system or installed component may not be necessary when the remaining operative equipment can provide an acceptable level of safety. Under the MEL, dispatch relief is granted for listed components and systems for specific periods of time before the system or component must be repaired or made operational. If repair is not made before the specified time period expires, the airplane may not be flown again until the repairs are made. The FAA uses several standard repair intervals that range from one flight to 120 days.

Primary Assumptions

As defined in the Tasking Statement, the FTIHWG's *Evaluations of all systems should include consideration of methods to minimize the cost of the system. For example, reliable designs with little or no redundancy should be considered, together with recommendations for dispatch relief authorization using the master minimum equipment list (MMEL) in the event of a system failure or malfunction that prevents inerting one or more affected fuel tanks.* The FTIHWG in general and the Airplane Operation and Maintenance Task Team specifically felt that these instructions were contradictory to the normal application of the MMEL.

These assumptions vastly affect the maintenance and operational costs for an airplane equipped with a fuel tank inerting system. Requiring system redundancy would greatly increase the cost and complexity of the inerting system and also would greatly increase maintenance and operating costs.

Likewise, if dispatch relief were not available on a system without redundancy, the maintenance requirements would be greatly increased. In addition, the rate of flight delays and cancellations would increase significantly because the system would have to be repaired before flight.

After lengthy discussions at the team and Working Group levels, we decided to proceed with the evaluation using the guidelines in the Tasking Statement. It must be understood, however, that airplane operations and maintenance costs would significantly increase with a change to either assumption. Because all FTIHWG analyses are based on these two assumptions, changing them would invalidate most of the results.

For purposes of the study, the Airplane Operation and Maintenance Task Team made an attempt to evaluate the impact of a category B or 3-day repair interval and a category C or 10-day repair interval. The impact was evaluated based on the reliability of the system, the typical amount of ground time between flights, and the typical maintenance capture rate or the frequency that an airplane overnights at a maintenance base. An effort also was made to predict the impact of having no dispatch relief, which essentially meant that one or more flights would be canceled while repairs were being accomplished. While these estimates are not comprehensive, they suggest the potential impact of the various options.

Frequency of Dispatch on MEL

To determine how frequently an airplane might be dispatched with the inerting system inoperative, the average annual flight-hours for the specific airplane category were divided by the inerting system reliability factor of MTBUR to determine the typical frequency of inerting system failures. Available time to troubleshoot and repair the system between flights is typically very short. Therefore, the assumption was made that, given the availability of dispatch relief per the MEL, maintenance would probably place the system on MEL and dispatch the airplane with the system inoperative rather than creating a lengthy flight delay.

Flight Delays

To dispatch an airplane with a system or component on MEL, some minimal amount of troubleshooting by a mechanic is required to identify the problem and verify that the system is safe for continued flight in its existing condition. The mechanic also must check the MEL to determine if there are maintenance procedures to deactivate or reconfigure the system before dispatch. The mechanic then must fill out the proper paperwork to place the system on MEL and release the airplane. The shorter the turn time, the more likely that a significant flight delay would occur. The availability of maintenance also is a factor because the number of available mechanics is very limited at many airports. Typical flight delays can range from a few minutes to several hours, depending on conditions, such as the maintenance workload at the time and weather. To reflect the potential impact on flight schedules for each dispatch on MEL, we assumed flight delay times (fig. 10-1) based on the typical turn time for that category airplane.

Airplane category	Flight delay per MEL dispatch, min
Large transport	30
Medium transport	45
Small transport	60
Regional turbofan	60
Regional turboprop	60
Business jet	60

Figure 10-1. Flight Delay Assumptions

The annual number of delays and delay time is then a function of the number of times the system fails and must be put on MEL times the estimated delay time in accordance with MEL dispatch.

10.1.3 Scheduled Maintenance

The Scheduled Maintenance Subteam was tasked with identifying and quantifying the costs and impact associated with the routine maintenance of an inerting system. Each proposed inerting system was addressed for each of the six airplane categories. (Airplanes were grouped according to standard seating configuration, and the airplane models were then placed into the six categories under consideration.) Because of the size and complexity of the onboard inerting concepts, however, we did not complete the analysis for turbofan, turboprop, or business jet categories.

Scheduled maintenance requirements should be minimal, based on the following assumptions:

- Most components will be maintained on condition.
- The system will be designed so that the risk of an undetected accumulation of nitrogen in spaces occupied by people or animals in flight or on the ground will be minimized.
- Failure of the inerting system will not provide any immediate risk to the airplane or its occupants.

A Boeing 757 (small airplane category) was chosen to establish a baseline of maintenance tasks and intervals. From there, we determined that maintenance intervals and data could be established for other airplane categories by scaling the Boeing 757 data as applicable.

To facilitate the calculation of scheduled maintenance labor-hours for each of the selected inerting systems, average use rates and maintenance intervals were obtained from Boeing and Airbus for all their jetliner models. From this information, we calculated the average maintenance intervals presented in figure 10-2. This information was used to determine the frequency, or portion, of each maintenance check per year. From that, we could establish the average additional labor-hours per year required for scheduled maintenance of an inerting system.

Airplane category	Check intervals, hr		
	A	C	Heavy
Large transport	650	5,000*	4C
Medium transport	500	4,350**	4C
Small transport	500	6,000**	4C
Regional turbofan	400	4,000	4C
Regional turboprop	500	3,200	9,600
Business jet	400	4,000	16,000

*Or 24 mo
**Or 18 mo

Figure 10-2. Average Fleetwide Maintenance Intervals

Maintenance Labor-Hours

We estimated maintenance labor-hours for the Boeing 757. These labor-hours were to be scaled to determine the additional scheduled maintenance labor-hours for other airplane categories, but no significant differences among categories were discovered. From the information available, components among airplane categories do not vary significantly. Although the size of components may differ, the scheduled maintenance labor-hours needed to inspect or remove and replace these components do not. When compared with a small-airplane category, medium- and large-airplane categories will require additional labor-hours during a heavy check to inspect the wiring and ducting of the additional wiring and tubing.

Scheduled maintenance tasks and inspection intervals for components within each concept were obtained using tasks and intervals for similar components on existing airplanes, or components performing similar functions on the V-22 Osprey. It is important to note that the V-22 Osprey currently operates with a fuel tank nitrogen inerting system.

To obtain the estimated labor-hours, the team identified maintenance tasks for similar components (e.g., components in ATA[2] 21, 28, and 36) used on in-service airplane models and then queried maintenance personnel as to whether the labor-hours per task were reasonable. The estimate was based partly on the expertise of the maintenance personnel because the actual locations of components will not be known until an inerting system is actually designed.

Cycles Versus Operating Time

It is important to note that GBIS and OBGIS maintenance intervals are based on cycles and an average system operating time per cycle. OBIGGS maintenance intervals are based on flight-hours plus ground operating time.

The team excluded scheduled maintenance for the GBIS at the heavy check for small, medium, and large airplanes. Because the amount of equipment internal to the airplane or the fuel tanks is limited, we assumed that C-check inspections would suffice.

Scheduled maintenance for the GBIS on turboprop and turbofan airplanes is required at heavy check because of the time between heavy checks.

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[2] Airplane manuals are divided in chapters according to ATA standards. Each chapter describes a specific airplane system. The ATA chapters referred to here are “Air-Conditioning” (ATA 21), “Fuel System” (ATA 28), and “Pneumatic System” (ATA 36), respectively.

Scheduled maintenance for the GBIS on business jets would be required annually.

Additional Maintenance Tasks

Numerous maintenance checks will be required but cannot be evaluated until final designs are determined. These would include, but are not necessarily limited to, preflight checks (i.e., BITE checks, fault checks, extended-range checks) and pretank entry checks (which will depend on the actual operator, the equivalent of OSHA, or both). In addition, we do not include unusual scheduled tasks based on the system chosen (e.g., daily warmup period for membrane OBIGGS).

We cannot include other scheduled maintenance items because of the peculiarities of each system, which will not be known until the system has been designed. Without knowing the design life of many of the components to be used in the proposed inerting systems, the team could not estimate labor-hours required for scheduled removals. These include specific consumables, other than filters, that are only required by the design itself (e.g., liquid nitrogen for the cryogenic inerting system).

The team recognized that a true picture of the maintenance program could be achieved only by performing an MSG-3 analysis. However, lack of design data prevented that from being accomplished for this report. (MSG-3 is a document produced by the ATA that outlines a decision and selection process for determining the scheduled maintenance requirements initially projected for an airplane system or powerplant.)

10.1.4 Unscheduled Maintenance

Component Reliability

As mentioned in previous sections, little or no documentation exists relating to the operation, maintainability, and reliability of airplane fuel tank inerting systems. The challenge for the team has been to develop a reasonably accurate method to estimate the reliability of the fuel tank inerting system design concepts.

After a review of each of the design concepts, the similarity between the proposed inerting systems and other existing airplane systems became evident. For many components, strong similarities exist with fuel, pneumatic, and air-conditioning system components that are currently used on commercial airplanes. In fact, there is a possibility that some existing valves, sensors, or fans currently used in other systems could be used in an inerting system. Therefore, for each inerting system component, the team identified as many similar airplane components as possible. The team gathered information on similar components and averaged available reliability data for those components. For components that are unique to the inerting systems, such as ASMs, the team used the manufacturers' estimates of the component reliability.

MTBF Versus MTBUR

We determined that the MTBUR would be a better indicator of the impact on the airplane maintenance requirements and operational performance than the system MTBF. Using MTBUR factors in some of the typical maintenance inefficiencies in system troubleshooting and repair, and therefore more accurately reflects the real-world problems encountered in airplane maintenance.

Airplane Use Rate

To ensure that uniform and consistent analysis methods were used to evaluate the effect on maintenance and operations, we determined airplane use rates for each of the study-category airplanes based on industry data (fig. 10-3). These use rates included daily and annual airplane flight-hours and the number of

	Daily flight-hours (hr)	Annual flight-hours (hr)	Flights per day (avg. no.)	Minimum turn time (min)
Large transport	11.18	4,081	2	60
Medium transport	7.65	2,792	3.5	45
Small transport	7.86	2,869	7	20
Regional turbofan	5.8	2,117	7.1	15
Regional turboprop	8.1	2,957	6.8	15
Business jet	1.37	500	1.5	60

Figure 10-3. Airplane Use by Category

System Reliability

The team calculated the system reliability as an inverse sum of the MTBUR inverses. We used the same method to determine the system reliability for each of the inerting system concepts.

System Annual Use Rates

Because of differences in the operating requirements and characteristics of each inerting system design concept, the amount of operating time a specific system experiences varies. System operating time is important because it directly affects system reliability and, therefore, operating costs. To account for these differences, the team developed the system annual use rates based on the operating requirements for each inerting system concept and each category of airplane.

System Annual Failure Rate

The team determined the inerting system failure rate by multiplying the system MTBUR by the system annual use rate for the category airplane. This rate was then used as an estimate of the frequency that the airplane would be dispatched with the system inoperative (MEL). We used it with the MEL repair interval requirements to estimate the percentage of time the system would be operational.

System Maintenance Workload

To determine the amount of additional workload an inerting system would add to an airplane’s maintenance requirements, the team made some assumptions about the location of the inerting system components. We worked with the design teams to identify the likely locations of components. Identifying potential locations on some airplane categories was relatively easy. On the 747, for example, the teams determined that an area beneath the CWT adjacent to the air-conditioning packs was large enough for an onboard system; it met most of the design and safety requirements. This location also would provide good access for maintenance. On other airplanes, space was limited. Many of these spaces were inside the fuselage pressure vessel, raising safety concerns, and they had poor access for maintenance. On some airplanes, space inside wheelwells and wing-to-body fairings was available. In many others, the only potential locations tended to be in the aft fuselage area just forward or behind the aft pressure bulkhead. The team also considered differences in access time as a result of the time necessary to purge the fuel tanks because of the differences in fuel tank volumes.

Based on this survey of potential locations, we developed estimates for troubleshooting, removal, and installation of each component. We used this estimate and the components’ predicted failure rate to develop a maintenance labor estimate for the system onboard each airplane category.

10.1.5 Flight Operations

To evaluate this process and come to the conclusions and recommendations stated further in this document, the team used several implications and assumptions. First and foremost was the assumption that, in the event the inerting system was inoperative or ground inerting equipment was not available, a means to dispatch the airplane without the fuel tanks inerted must be defined. Much discussion went into this decision, ranging from requiring inerting on every flight regardless of circumstances to treating the system as supplementary only. In the event that MEL or dispatch relief was not available, operators would incur major limitations. The scope of such limitations could be great enough to change entire route structures. Airports that could not provide nitrogen or maintenance procedures would not be available as alternatives, refueling stops, or diversions because their use would have the potential to ground airplanes and passengers short of their destinations. If inerting systems were required for safety of flight, then additional air turnbacks, flight cancellations, and delays would also have to be considered. This and the guidelines set forth in the Tasking Statement led us to our final premise. Consequently, our evaluation and methodology regarded the system as being a safety enhancement system similar to the present traffic collision and avoidance systems required on airplanes today.

The cost-to-carry estimates are a function of the weight of the system and the cost of the fuel to carry the additional load. The loss of revenue from the decrease in useful load on flights routinely operating at maximum gross weight is also considered. Because determination of the cost associated with the production of power and the resulting drag incurred by onboard systems requires detailed design data, we have not quantified these costs.

We derived flight crew procedures and associated training expenses from past typical training events similar to the requirements of the proposed system. We also assumed that an AC will be published by the FAA as a training aid from a high-level or general standpoint.

Based on the assumption that fuel tank inerting systems would not be considered a requirement for safety of flight, the Airplane Operation and Maintenance Task Team concluded that in-flight indication requirements for an onboard system would be minimal. The flight crew must be able to shut down the system in case of a catastrophic failure and would need some indication of inerting system status. This could include positive indication that the system had powered down in the event of manual system shutdown. Failure of an onboard inerting system would also be annunciated to maintenance personnel after landing. These assumptions reduce the potential for flight delays, diversions, air turnbacks, and their associated costs. Any change in the assumptions would greatly increase flight interruptions and operating costs.

10.1.6 Ground Operations

The effect an inerting system has on ground operations depends on the system concept being considered. Training, ground handling, and line maintenance requirements were considered along with the associated costs. To accomplish this, we developed conceptual models of operations with ground-based and onboard inerting systems based on inerting system concepts and airline operational experience.

The team also assumes that the FAA will provide an AC that addresses training for operators and technicians. Recent modifications to 737 CWTs and installation of smoke detection and fire suppression systems in class-D cargo compartments allow the team to draw some parallels in the processes under review. Based on the modification and training requirements involving these systems, a generic description of the model follows:

Training programs for line maintenance technicians should cover system operation, MMEL processes, and special procedures, including troubleshooting procedures. While operator training requirements and internal policies and procedures vary widely, task-specific training for technicians accomplishing the initial airplane modification should be implemented. A separate or additional program dealing with nitrogen safety and usage should be developed for those individuals working around the airplane during inerting. This team estimates that 8 hr of initial, and 4 hr of annually recurring training would be required for each technician.

10.2 MAINTENANCE IMPACTS

The retrofit and operation of any of the proposed inerting systems will significantly affect airplane maintenance programs and schedules, dispatch reliability, maintenance workload in the line environment, and safety of the maintenance personnel.

10.2.1 Modification and Retrofit

This team concludes that because of the scope of the modifications, most operators would not be able to schedule the modifications to incorporate the inerting system during an airplane's regular heavy maintenance visit (app. F, add. F.A.1). The additional labor-hours would extend the scheduled maintenance visit so much that it would interfere with the airline's maintenance schedules. Operators must complete the maintenance requirements on schedule or risk grounding airplanes. Most operators would likely start dedicated modification lines or contract the modifications out to other maintenance facilities. The disadvantage of this approach is that the existing access available during heavy maintenance visits would be lost. This would increase the total labor-hours required for the modification. Another disadvantage of this approach is that it may cause a worldwide problem with hangar availability. The team estimated that approximately 100 dedicated hangars would be necessary for modification of the existing fleet during the proposed compliance period. If the operators need to perform the modifications in a special modification line extra slots are necessary; this may result in insufficient hangar space.

Because of the number of airplanes affected, the Airplane Operation and Maintenance Task Team has serious concerns about the availability of trained maintenance technicians required to modify the airplanes within the proposed compliance period. Completing the modification of all the affected airplanes in a 7-year period would require 3,000 to 4,000 trained maintenance technicians working full time.

10.2.2 MEL Relief

The assumption of dispatch relief for the fuel tank inerting system is fundamental to estimating its potential impact on airplane operations and maintenance. If the assumption changes, the approach to evaluating the scheduled maintenance requirements would also need to change, resulting in a significant increase in estimated time and costs.

If a typical airline could not dispatch an airplane with its inerting system inoperative, the airplane would have to be taken out of service to repair the failed inerting system. The result would be a heightened burden on the airline's line maintenance functions to get the airplane back into service. Therefore, airlines would most likely focus on the inerting system's scheduled maintenance program, driving many components off the airplane for overhaul earlier in an attempt to reduce system failures in service. This would significantly increase the scheduled maintenance, overhaul, and operating costs for the inerting system.

10.2.3 Scheduled Maintenance

As shown in the specific inerting design concept sections, scheduled maintenance impact reflects access, inspection of component, and closure, but does not reflect any nonroutine correction of discrepancies. Neither does it include the cost of any special equipment or tooling required to accomplish the inspections or any of the costs related to the airplane's modification. It begins after the inerting system has been incorporated.

The heavy check inspections shown for the different inerting design concepts do not reflect any additional workforce required to comply with safety requirements for fuel tank entry into confined spaces with NEA present.

Airplane fuselage seal deterioration occurs because of increasing airplane age, and pressure decay checks allow discovery of seals that require replacement or rework. The use of cabin air to supply the inerting system increases the demand on the airplane air-conditioning packs. Consequently, the maximum allowable cabin leakage rate will have to be maintained at a lower level to ensure that the air-conditioning packs will continue to maintain the required cabin pressurization.

We have added extra labor-hours to each C- and heavy check to allow for a fuselage pressure decay check and rectification if cabin air is used to supply the inerting system. Operator experience has shown that in-service airplanes periodically require a pressure decay check in order to maintain limits prescribed in airplane maintenance manuals.

The extra labor-hours are averages obtained from those operators whose maintenance programs currently require fuselage pressure decay checks.

10.2.4 Unscheduled Maintenance

Each of the design concepts included in this study, from the least complex (GBI) to the most complex (OBIGGS), will affect line maintenance, as will the introduction of any new system onto an airplane. From a general perspective, the introduction of a new system, and hence the introduction of new components or line-replaceable units, will affect line maintenance by affecting airplane dispatch reliability.

In simple terms, the more components there are, the less reliable the system, resulting in a lower overall airplane dispatch reliability rate. The reliability of each component or line-replaceable unit and its MTBUR directly relates to unscheduled line maintenance activity. This in turn means increases in labor-hours (i.e., troubleshooting, component access, and component removal and replacement times), material, and labor costs, and most likely in airplane delays and cancellations. The introduction of a new system and its components can also affect other systems by limiting access to their components, thus affecting unrelated component replacement times.

The specific effect on line maintenance as a result of the introduction of inerting is best evaluated by looking at component MTBUR data for similar or related systems. The effect on other systems resulting from operating the various inerting systems must also be considered. For example, the proposed OBIGGS design concept extracts cabin air as an air source during certain flight phases. Although a scheduled maintenance task to accomplish a periodic fuselage pressure decay check will need to be implemented, cabin air extraction will undoubtedly affect airplane pressurization, especially on older airplanes. This leads to unscheduled maintenance activities and associated costs to isolate and rectify air losses. The effect on line or unscheduled maintenance varies depending on the inerting system used. We discussed these differences in more detail in each of the system design concept sections.

We did not include unscheduled maintenance costs associated with component overhaul, including labor and material costs, and costs associated with special equipment and tooling in the analysis because of insufficient data.

Special precautions must be taken when performing line maintenance on some inerting system components such as confined space entry procedures, depending on their location. Additional hazards associated with gaseous and liquid nitrogen must also be considered. These special precautions and additional hazards result in increased line maintenance costs through increased training (both initial and recurring), equipment, and procedure and policy implementation. The specific issue related to maintenance personnel safety associated with nitrogen inerting systems is discussed in more detail in the Maintenance Safety section.

Because of the unique safety precautions associated with performing line maintenance tasks on inerting system components, specially trained line maintenance personnel would be required, similar to wet cell entry-skilled personnel. Some airlines may use contracted personnel to perform such tasks.

10.2.5 Maintenance Training

To provide a safe working environment, operators are required to provide maintenance training before introducing an inerting system. Training instructors may need to modify their schedules, additional instructors may need to be hired, and training personnel may need to attend vendor and manufacturer classes. Afterward, these instructors will need to spend time adapting vendor training materials to their operators' standards. Only after the new training material is finished and approved by the local regulatory authorities can regularly scheduled classes begin for maintenance and ground support personnel. The variety of airplane fleets and available inerting systems will require mechanics and ground support personnel to be trained for all systems applicable to all airplane categories in the operator's fleet. This fuel tank inerting training requirement will consist of classroom lectures, jet airplane maintenance fundamentals, CBT courseware, and basic training workshops, as well as practical training on in-service airplanes after the new system is introduced.

10.3 OPERATIONAL IMPACT

The installation and operation of a fuel tank inerting system on an airplane significantly affects the daily operations of that airplane, its flight crew, and its ground support personnel. System reliability affects flight schedules and airplane dispatch rate. Flight crews will have to monitor the system to maintain operational safety. Ground support personnel will have to service ground-based systems, and everyone working on or around the airplane will have to be aware of the potential hazards associated with working around large quantities of nitrogen.

10.3.1 Flight Operations

Schedule, MEL and dispatch relief, lost revenue, operational safety, and training will likely have the greatest impact on flight operations. The following is a brief discussion of the severity of the impact in relation to the degree of restriction in a final rule. The impact ranges from inerting having a relatively minor impact on flight operations to its being rendered impractical in service.

10.3.1.1 Schedule Impact

Potential impacts to flight schedules will vary greatly depending on the type of inerting system used, the type of operation, and the availability of MEL and dispatch relief. Schedule delays from inadequate turn times are likely to be significant in those operations that routinely turn their airplanes around in less time than the systems were designed to accommodate. These types of delays are most likely to occur while using GBI. To minimize the potential impact on flight operations, we collected average minimum turn time data (fig. 10-4) from operators to determine the design goals for the inerting system concepts. This data was used by the Ground-Based Inerting Design and the Onboard Inerting Design teams to minimize the impact of inerting on airplane turn times. Under normal situations, the concept design goals preclude the requirement for extended gate time, however, some operators with very quick airplane turns could still be affected.

	Average minimum turn time (min)	Average airplane cycles per day	Airplane annual use rate
Small transport	20	7	2,869
Medium transport	45	3.5	2,792
Large transport	60	2	4,081
Business jet	60	1	500
Regional turboprop	15	6.8	2,117
Regional turbofan	15	7.1	2,957

Figure 10-4. Average Minimum Turn Times

The costs associated with such delays may be quantified by taking the percentage of flights that normally operate below the minimum scheduled time and multiplying it by the industry standard delay costs for each minute incurred.

MEL and dispatch relief, or lack thereof, have the greatest potential to escalate costs exponentially. The following section addresses this issue more fully. The installation implementation time for this proposal may also have a great effect if the modification cannot be accomplished during normally scheduled maintenance visits.

Airplane Out-of-Service Time

Most operators would not be able to schedule the inerting modification project during a regular heavy maintenance visit because of the scope of the project (app. F). The large number of required labor-hours would significantly extend the maintenance visit, which in turn would disturb the airline's operational schedule.

10.3.1.2 MEL Relief

The potential impact of MEL and dispatch relief, or lack thereof, cannot be emphasized enough, especially for onboard inerting systems. Without dispatch relief, every system malfunction would likely result in one or more flight cancellations. With estimated system failure rates ranging from two to six per year for each airplane, the average operator could experience 1,000 to 2,000 additional flight delays and cancellations per year.

10.3.1.3 Lost Revenue

The factor of lost revenue is an issue only on the percentage of flights operating at or near maximum takeoff weight for the specific flight. We took no other flights into consideration because the additional weight of the inerting system would not be expected to affect the planned revenue load. See appendix F for costs associated with this function. Cost to carry, however, must be applied to all systems on every flight. This is basically a function of design weight multiplied by the average industry cost per pound to demonstrate the increased fuel burn required to support the system. See appendix F for industry average costs to carry specific weights. These costs will vary greatly according to fluctuations in fuel prices. The costs associated with producing the power to run systems, such as electrical load, bleed load, or drag, will also need to be considered.

10.3.1.4 Flight Operations Safety

The major safety issues relating to flight operations are in regard to NEA leaking into the cockpit or passenger cabin and the accumulation of highly concentrated oxygen at or near a fuel source. Because of these concerns, it is recommended that nitrogen- and oxygen-level sensors be installed to provide a warning in case of a leak in critical areas. Flight crews and cabin crews will also need to be trained on how to react in the event of such an alarm. Under normal in-flight conditions, the air-conditioning system on an airplane will supply sufficient fresh air to prevent leaks from reducing the oxygen level in the cabin. However, under abnormal conditions and on the ground this may not be the case. We believe strongly that this warning system will be required to prevent subsequent loss of life in case of an unknown failure.

10.3.1.5 Flight Operations Training

Flight operations training for the purpose of this report will include training requirements for both pilots and dispatchers. A general course should be administered to both groups describing the benefits and hazards associated with nitrogen inerting systems. Also, a review of the basic fire triangle and flammability characteristics of jet fuel should be conducted to familiarize both groups with the dangers associated with warm ullage temperatures. This will allow them to evaluate operational practices, such as ground air-cart usage on warm days, to control these circumstances. Dispatchers will also need to be trained to understand any dispatch deviation requirements necessary for dispatch with an inoperative inerting system. Pilot training requirements vary greatly depending on equipment type, inerting design, and operational environment. For example, a corporate pilot operating in or out of a remote airport may have responsibilities that a pilot in airline operations may not. A typical in-house training program would basically consist of a training bulletin followed up by a regularly scheduled module during recurrent training. Outside or contracted training would typically consist of a training program established by a commercial training facility and administered during special training events. Both would greatly benefit from an AC provided by the FAA to assist operators with developing training materials.

10.3.2 Ground Operations

Installation and operation of any inerting system will affect ground operation regardless of which inerting concept is considered. Introduction of any system will add new considerations regarding safety, new tasks, or dealing with new support equipment. Obviously, GBI has the largest impact on ground operations because of the servicing requirement before each flight.

10.3.2.1 Ground Operations Safety

The safety training course for ground operations should include the hazards of nitrogen and other inert gases. Some gases such as nitrogen are particularly insidious because of their poor warning properties. Oxygen-depleted environments from the inerting process have been reported to cause fatalities to workers in confined spaces. NIOSH has provided data from a 10-year study (National Traumatic Occupational Fatalities Data) pertaining to the number of victims in single and multiple fatalities for all types of confined-space incidents.

A startling 585 separate fatal incidents in confined spaces claiming 670 lives occurred within the 10-year study period. This data strongly underscores the need for increased ground operational safety requirements by all operators before introducing any inerting systems. Because of the nature of this type of gas, confined areas such as cargo bins and equipment bays are particularly susceptible to this hazard.

The minimum ARAC recommendation is that all ground operation personnel be aware of these dangers and know what to do in the event that something goes wrong while using nitrogen to accomplish inerting. Airport fire, rescue, and safety personnel would also require additional training on the uses of nitrogen and confined-space rescue in airplane fuel tanks.

The possibility of overpressurizing the airplane fuel tanks is also a serious safety concern when using nitrogen to inert the ullage. This concern can be alleviated by having trained technicians safely and efficiently perform inerting.

10.3.2.2 Ground Operations Training

Mandatory awareness training on the dangers of using nitrogen in the quantities required to inert airplane fuel tanks is recommended. An 8-hr initial program should be provided for all technicians involved with installation and servicing.

We recommend up to a 4-hr annual recurrent program to maintain the heightened awareness on the hazards of working with nitrogen in these volumes. As an example, 1 hr could include a video on servicing while another hour encompasses troubleshooting and servicing. The remainder of the time can be used for applicable system training and open discussions. Other groups working on and around the airplane should also be aware of the dangers associated with nitrogen. These groups should receive recurrent safety training annually. These different groups should include but are not limited to cleaners, fuelers, baggage handlers, caterers, ticket and customer service agents, flight attendants, and pilots. The video, for example, may adequately educate these individuals on the dangers and cautions involved with nitrogen inerting.

For maintenance training purposes, a $75 per hr rate provided by the FAA (app. G) establishes a value for estimating an operator's cost to properly train a technician to install and service inerting systems. All other group rates will vary respectively.

10.3.2.3 Ground Servicing

With the above-mentioned dangers of using nitrogen to inert airplane fuel tanks, the servicing of airplanes with GBI systems should not be performed by ground service employees unless they are specifically trained maintenance technicians for the required inerting task. With the continual industry concerns with on-time performance, having the technician in place will help facilitate that process. Numerous discussions took place on this topic and this group concluded that, after the system has been in operation for several years, reconsideration could be given to who should perform the inerting task.

Trained technicians with a thorough understanding of the system and the consequences of improper operation would be better prepared to monitor and interrupt the inerting process at all times for diagnosis and troubleshooting of system anomalies. To enhance on-time performance, having a technician in place will provide the operator with immediate troubleshooting capability for a system discrepancy during the inerting process, thus minimizing any ground delay from maintenance problems associated with the inerting system. This process would require technicians in all airplane stations, and considerations should be given to contract maintenance personnel requirements at locations not staffed by operator-employed technicians.